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# Study on effect of installation position of prime movers enlarged cross-sectional area on oscillation temperature in loop-tube-type multi-stage thermoacoustic system

ループ管方式多段熱音響システムにおける断面積拡大プライムムーバーの設置位置の検討

Tatsuya Ishino[1‡], Shin-ichi Sakamoto[1], Yuichiro Orino[1], Yoshitaka Inui[1], and Yoshiaki Watanabe[2] ([1]Univ. of Shiga Pref.; [2]Doshisya Univ.)
石野 達也 [1‡]，坂本 眞一 [1]，折野 裕一郎 [1]，乾 義尚 [1]，渡辺 好章 [2] ([1] 滋賀県立大, [2] 同志社大)

## 1. Introduction

In the past, thermoacoustic systems[1)] have been studied for solving energy problems. Thermoacoustic systems are systems that use the mutual conversion of energy between sound and heat (thermoacoustic phenomenon). A thermoacoustic system utilizes unused heat sources because it operates on the heat input from external. sources. Thermoacoustic systems have the advantages of long-life and cost effectiveness because they have a simple structure with no moving parts. On the other hand, these systems require a high driving temperature. Therefore, the driving temperature of the system should be decreased to utilize unused low-temperature heat sources.

Here, a loop-tube-type thermoacoustic system, one of the forms of thermoacoustic systems, is studied. Thermoacoustic self-sustained sound is generated in the loop tube. The system can be used for cooling and generating electricity with sound wave in the loop tube. A loop-tube-type thermoacoustic system has prime movers that convert heat to sound energy. A prime mover consists of heat exchanger 1 (high temperature) , a stack, and heat exchanger 2 (low temperature) . Thermoacoustic phenomenon is caused by heat exchange between the stack wall and fluid particles in the stack.

In this paper, we focused on prime movers for low-temperature driving. When multistages prime movers are installed in series, thermoacoustic systems can be driven at low temperature[2), 3)]. In a loop-tube-type thermoacoustic system, we studied on the effect of relative installation position of the prime movers by a stability analysis[4), 5)] and an experiment.

## 2. Experimental system

Figure 1 shows a schematic of the experimental system. The loop-tube-type system

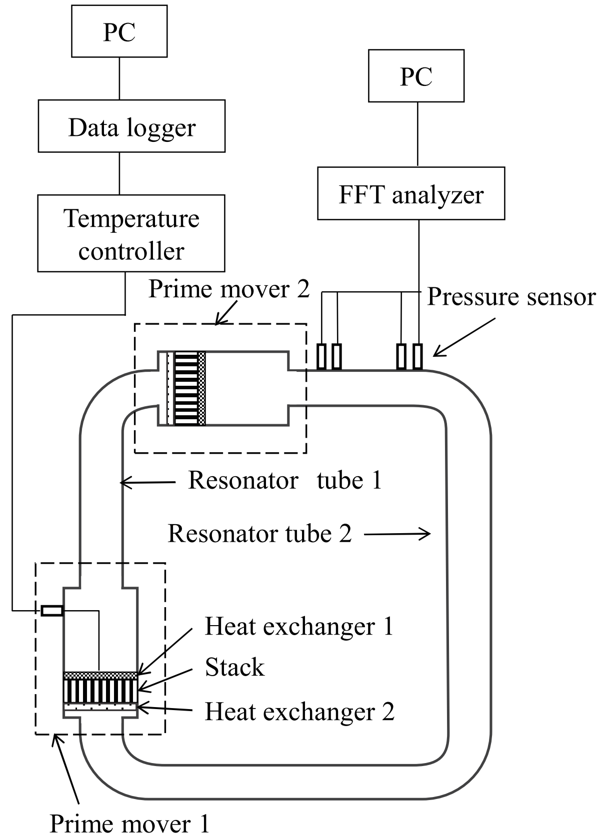


Fig. 1 Schematic of experimental system.

comprises a stainless steel tube. Atmospheric air is filled in the loop tube. The length of the loop tube is 5.12 m. The inner diameter of the resonator tubes is 42.6 mm. The inner diameter and length of the prime movers are 100 mm and 330 mm, respectively. The stacks (honeycomb ceramics with a length of 50 mm, external diameter of 94 mm, and channel density is 900 channel/in$^2$) were located in the prime movers. Heat exchanger 1 is a spirally wound electric heater. Water at 20°C is circulated to maintain a constant temperature of heat exchanger 2. In this paper, the heat pump was omitted to simplify the generation of the sound field in the loop tube.

The relative position of both prime movers

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zn23tishino@ec.usp.ac.jp

was changed by varying the length of resonator 1 and resonator 2 while maintainig a constant total length. Temperatures of central areas of high-temperature ends of both stacks were measured using K-type thermocouples. The temperatures of the high-temperature ends of both stacks were kept constant using temperature controllers. In order to determine the onset temperature, the temperatures of the high-temperature ends of both stacks were gradually raised from room temperature (25°C). In order to confirm the oscillation, sound pressure in the loop tube was measured using pressure sensors mounted on it.

## 3. Analysis and Results

The critical temperatures of the high-temperature ends of both stacks were analyzed through a linear stability analysis using the transfer matrix method.[4), 5)] We analyzed the resonance modes of one, two, and three-wavelength with respect to the total length.

Figure 2 shows the experimental onset temperature and the analytical critical temperature obtained using the stability analysis for varying length of resonator 1 and resonator 2 with a constant total length of the loop tube. The horizontal axis of Fig. 2 indicates the normalized relative installation position of the prime movers. When the value of the horizontal axis is zero, the length of resonator 1 is zero. When value of the horizontal axis is one, the length of resonator 2 is zero. Only the one- and two-wavelength resonance modes are shown in Fig. 2 because the critical temperature of the three-wavelength resonance mode was higher than that of the one- and two-wavelength resonance modes in any condition.

In the experiment, the frequency of sound wave in the loop tube was measured at the onset of oscillation, and resonance mode was determined. One- or two-wavelength resonance modes were generated with respect to the installation position of the prime movers. Figure 2 shows that the critical temperature of the one-wavelength mode is generally lower than that of the two-wavelength mode; however, in specific installation positions, the critical temperature of the two-wavelength mode is lower than that of the one-wavelength mode. In such positions, experimental resonance modes resulted in the two-wavelength mode.

Figure 2 shows that the experimental onset and analytical critical temperature vary with respect to the installation position. The onset temperature is lowest at a normalized position of 0.17 (where the length of resonator 1 is 750 mm). The critical temperature is lowest at approximately the same position. Analytical results are in

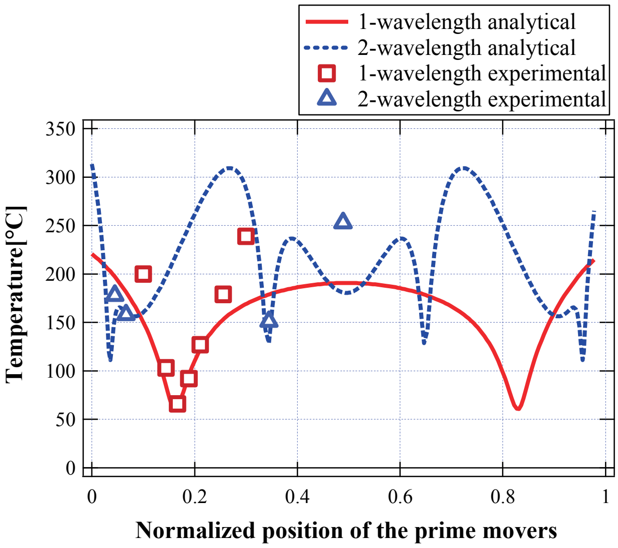


Fig. 2 Oscillation temperature vs relative position of the prime movers.

qualitative agreement with experimental results. The lowest onset temperature is 67°C and the lowest critical temperature is 61°C.This indicates that there is a possibility of effectively utilizing low-temperature waste heat.

## 4. Conclusions

We investigated the effect of the relative position of the prime movers in a loop-tube-type thermoacoustic system for a low-temperature driving. The analytical critical temperature and experimental onset temperature decrease on adjusting the relative installation position of the prime movers. The analytical resonance modes and temperature are in qualitative agreement with experimental results.

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